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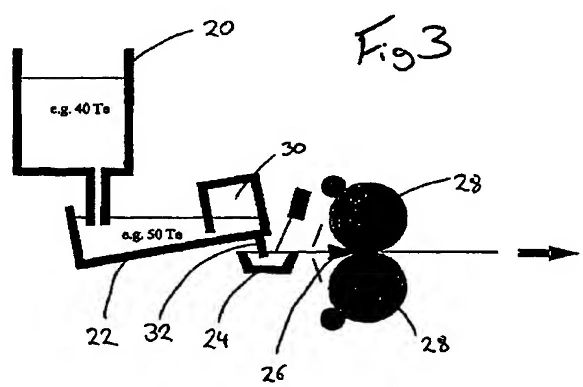
(54) **Improvements in and relating to casting**

(57) A method of casting is provided in which molten material is fed from a source of molten material, such as a ladle, to a vessel, the vessel feeding molten material to a casting location. The molten material is fed to the casting location substantially continuously during casting, but the molten material is fed from the source to the vessel for only a part of the time of casting, for instance, less than 75%.

It is a preferred feature that the volume of molten material in the vessel can be varied, but that the head of molten material over the outlet passage from the vessel is substantially constant. A tilting tundish to achieve this aim is provided.

The invention provides advantages in terms of the flexibility of timing of molten metal delivery to the casting system.



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Description

This invention concerns improvements in and relating to casting of molten materials, particularly molten metal being cast into strips, slabs or other forms.

Strip and slab casting typical involves feeding molten steel through a casting nozzle and then between rollers to give the desired strip/slab thickness. The molten metal feed to the nozzle comes from a tundish which is fed from a delivery ladle. To maintain a constant casting rate the level of molten material within the tundish is kept constant throughout the majority of the casting stage by balancing the pouring rate from the ladle into the tundish against the extraction rate from the tundish via the casting nozzle.

As the ladle represents a batch delivery system to the tundish it must periodically be replaced by another full ladle. To ensure a sufficient level of material in the tundish during change over, the level can be increased slightly before hand. The tundish level depletes during change over until the level can be topped up once more by the replacement ladle.

Unfortunately this process necessitates replacement ladles being available at regular and uninterrupted intervals as well as a consistent and fast ladle change method. This constant demand places a severe restraint on the melt shop and its efficiency.

It is possible to reduce the casting rate to provide a delay in which a replacement ladle can be brought forward but this in turn causes problems. Reducing casting speed can have a significant effect on the strip quality, particularly for the thinner strip sizes, as this increases the amount of reduction of the strip between the rolls. Reduced casting speed can also lead to the metal in the unheated ladle cooling to an extent where it freezes in a variety of locations including the nozzle and tundish control valves.

In conventional slab casting plants the use of speed is more applicable as broader casting speed ranges are available for casting quality products.

The present invention aims to provide greater versatility and control in the casting system.

According to a first aspect of the present invention we provide a method of casting comprising feeding molten material to a vessel from a source of molten material, the vessel feeding molten material to a casting location through an outlet passage, the volume of molten material in the vessel being variable, the head of molten material over the outlet passage being substantially constant independent of the volume of molten material in the vessel.

Preferably the vessel is a tundish. The tundish may be heated. The tundish may be heated by induction heating and/or plasma heating. Preferably the tundish has a capacity of between 20 and 120 tonnes.

Preferably the ratio of maximum to minimum working volume of the vessel is greater than 1.5:1 and more preferably greater than 1.75:1 or even greater than 2:1.

Preferably the vessel is provided with an enclosed head space above the inlet from the vessel to the outlet passage. The enclosed head space may be provided with a controlled or inert atmosphere. The surface of the material in the vessel may be provided with oxidation inhibitors, such as tundish powders. Preferably such materials are excluded from any enclosed head space.

Preferably the source of molten material is a ladle. Preferably the ladle is used to transfer molten material from a melting location to the casting location. Preferably the ladle is unheated. The ladle preferably has a capacity of between 10 and 100 tonnes of molten material. The material is preferably fed from the ladle to vessel under gravity. Control valves may be used to regulate the flow.

The flow rate of material from ladle to vessel is preferably at least 1.5 times greater than the casting flow rate, more preferably at least 3 times and may be as high as 5 times the rate.

Preferably the molten material is a metal, including alloys. Most preferably the material is steel.

Preferably the casting location comprises a casting nozzle. The casting nozzle may feed molten material direct to casting rollers. The casting nozzle may feed material to a pool in proximity to casting rollers.

The casting location may be fed with material via a fixed or flexible link. The feed may be direct from the vessel or via intervening means. The feed is preferably affected by gravity. Control means, such as valves, may be provided to regulate the flow.

Preferably the vessel can be adjusted to accommodate varying volumes of material whilst maintaining a constant head. The variation in volume may be provided by varying the volume of material accommodated within the vessel away from the outlet. Preferably the variation is accommodated on a continuous basis during casting.

The variation may be accommodated by altering the position of the vessel. The variation in the positioning may occur through tilting the vessel or pivoting it. The pivoting or tilting may occur about one, preferably fixed, axis.

Preferably the vessel has a volume portion adjacent to the outlet passage and a volume portion distal to the outlet passage. Preferably the volume accommodated in the vessel is increased by lowering the level of the distal portion relative to the level of the portion adjacent the outlet passage. preferably the volume is decreased by raising the level of the distal portion relative to the level of the portion adjacent to the outlet passage.

The tilt or pivot may occur about a fixed location. Preferably the fixed location is about the outlet passage. The fixed location may be at the outlet from the outlet passage into an intervening vessel.

The adjustment of the vessel to maintain a constant head may be based on level measurements in the vessel and/or based on mass of material in the vessel.

Preferably the head is maintained at a value related to the casting rate. In this way casting quality can be

maintained.

The head is preferably measured in the vertical direction. The head measured may be measured in terms of the projected head based on the vertical separation of the molten material level in the vessel and the outlet level to which it is feed. A head of greater than 300mm may be provided. Preferably the head is maintained at a minimum without causing vortexing of the metal. The outlet level may be the casting location where material is fed direct from the vessel to that location. The outlet level may be the level in an intervening vessel between the vessel and casting location where the material is fed to such a vessel prior to feeding to the casting location. The intervening vessel may comprise a headbox. The exit of material from the headbox to the casting location may be controlled by a weir or dam.

Preferably the method is used for casting strips, slabs, blooms and billets. Its use for casting strips of thickness less than 10mm is particularly preferred. Preferably the material is cast at a rate of between 5 and 150 tonnes per hour and more preferably between 10 and 100 tonnes per hour.

According to a second aspect of the present invention we provide casting apparatus comprising a source of molten material, a vessel to which the molten material is fed, the vessel feeding material to a casting location via an outlet passage, the vessel being adjustable to present a constant head of material independent of the volume of material accommodated within the vessel.

Preferably the vessel is a tundish. Induction heating and/or plasma heating means may be provided for the tundish.

Preferably the vessel is provided with an enclosed head space above the inlet from the vessel to the outlet passage. The enclosed head space may be defined by portions of the vessel which dip below the surface of the molten material in the vessel to separate enclosed and unenclosed portions.

Preferably the source of molten material is a ladle. Preferably the ladle is unheated. The ladle may be provided with control valves to regulate the flow of material from the ladle to the vessel.

The casting location may comprise a casting nozzle. The casting nozzle may be provided with a flexible link or fixed link from the vessel or from an intervening vessel fed from the vessel. The feeder material from the vessel to casting location may be regulated by control means as valves.

Preferably the vessel is pivotally mounted. Preferably the vessel is pivotally mounted about one, preferably fixed, axis. Preferably the pivot location is about the outlet passage, and most preferably about the outlet from the outlet passage into an intervening vessel.

The apparatus may be provided with mass and/or level monitoring means for the vessel and/or for the intervening vessel.

The intervening vessel may comprise a head box. The head box may be provided with weirs, dams or other flow regulating means.

According to a third aspect of the invention we provide a method of casting comprising feeding molten material to a vessel from a source of molten material, the vessel feeding molten material to a casting location, the molten material being fed to the casting location substantially continuously during casting, the molten material being fed to the vessel from the source for less than 90% of the time during casting.

Preferably the molten material is fed from the source to the vessel for less than 75% of the time during casting, more preferably less than 50% of the time and still more preferably less than 33% of the time.

Other details of the first and second aspect of the invention may be based on features set out elsewhere in this application.

Embodiments of the invention will now be described, by way of example only, and with reference to the accompanying Figures in which :-

Figure 1 illustrates a variety of casting nozzle configurations and positions;

Figure 2 illustrates a prior art casting system;

Figure 3 illustrates an embodiment of the casting system of the present invention;

Figure 4 illustrates a series of tundish configurations in various stages of a casting system's operation according to the invention; and

Figure 5 illustrates the variation in a variety of the parameters for a casting system according to the present invention against time.

Steel strips and slabs are generally produced by feeding molten metal through a nozzle into a casting machine and then rolling the material in a series of stages to the desired thickness and width. The cast material sizes prior to rolling vary from 2 to 6mm thicknesses and widths upto 2000mm for strips through thin slab (50 to 120mm thick, 700 to 2000mm wide), midi slab (120 to 185mm thick, 700 to 3200mm wide) to thick slab (185 to 300mm, 700 to 3200mm wide).

As a consequence of the varying thickness of steel being cast the flow rates between strip and slab casting vary significantly. A typical strip casting operation may employ flow rates of between 10 and 100 tonnes/hour.

A series of such nozzle 1 and casting roller 3 arrangements are illustrated in Figure 1a to 1d for a strip casting operation. As shown casting can occur at a variety of orientations. Equally the casting can occur direct from the nozzle 1 to rollers 3, as in Figures 1a, 1b and 1d, or via a localised pool 5 of molten metal in proximity to the rollers 3, as in Figure 1c.

In all casting systems it is imperative that an adequate supply of molten metal to the nozzle is provided

throughout casting and also to ensure that the casting temperature is accurately controlled.

In a typical prior art casting system, Figure 2, molten metal is delivered to the casting apparatus in unheated ladles 10. It is desirable to keep the ladle size as large as practically possible to minimise scrap losses. The ladle 10 is gradually emptied into tundish 12 which in turn feeds the casting nozzle 14. Metal leaving the nozzle 14 passes between rollers 16 and onto subsequent rolling and processing.

Throughout the substantial part of the casting process the flow of metal from ladle 10 to tundish 12 is balanced against an equal flow from the nozzle 14. The tundish level thus remains constant throughout the process, a constant mass of metal is present in the tundish 12. Variation in level only occurs during ladle change over. The prior art systems aim to minimise this variation by using fast ladle change mechanisms and possible reducing casting speed during the change. Variations at other times are minimised using level control based on metal flow.

It is important to maintain a substantially constant flow rate of metal to the nozzle and to maintain a depth of metal in the tundish above a certain threshold. If the depth decreases too far vortexing can occur drawing undesirable material into the metal, for instance tundish powders. A depth of around 400mm is typical for slab casting with lower depths for the lower flow rates of strip casting. The necessary depth increases with increasing flow rate.

To maintain the depth during the majority of the process the flow is balanced by pouring from the ladle to the tundish. As the ladle approaches empty another is readied. The last part of the ladle volume can be emptied at a higher rate into the tundish to give a slight increase in level for a very limited portion of the cycle of the casting. The empty ladle is then withdrawn and replaced by another. This further ladle can then be emptied into the tundish in a similar manner to the first to initially restore the tundish level and then to balance the flow from the nozzle.

A constant supply of ladles in this way presents a severe constraint to the operation of the melt shop. Whilst in certain slab casting applications the casting speed can be reduced to reduce the rate at which material is drawn from the tundish and thus allow further time in which to obtain an additional ladle this process is prone to problems. Thicknesses below 50mm cannot successfully be achieved using such techniques and even above this size performance is impaired. Problems stem from the increased cooling which occurs with slower pouring. The ladle 10 is unheated and thus loses heat during use. The slower the pour, the greater the time to dispense its volume and hence the lower the temperature of the metal dispensed as the pour progresses. The variation in temperature causes problems. Furthermore by the end of the pour the temperature may have decreased to such an extent that the metal solidifies within the system. Freezing is particularly prone to occur in the tundish and nozzle control valves.

The present invention provides a system with a synchronous metal feed. The molten metal is obtained and transferred to the system in the standard way using a ladle 20. The ladle 20 is discharged into a heated tundish 22. Plasma, induction and other heating systems may be provided. The tundish 22 in turn feeds a headbox 24 and hence to the casting nozzle 26. Casting from the nozzle 26 through rollers 28 follows the general principals of the prior art. Unlike the prior art the tundish is fed from the ladle at a far higher rate than it discharges, in this case approximately 5 times. For significant periods of the casting cycle therefore no metal is being fed to the tundish.

Based around an example of a 40 tonne ladle of steel this is discharged into the 50 tonne capacity tundish at approximately 1 tonne/min until empty. At such a high discharge rate there is no risk of the metal cooling to an undesired degree. The risk of freezing in the ladle control valves is thus avoided.

Once the tundish contains 15 tonnes it contains sufficient material to allow effective casting and material is fed to the nozzle at the rate of 0.2 tonne/min.

Using this system the ladle is emptied long before casting has finished from the tundish. In this way the system allows a substantial time period in which another ladle can be readied. A new ladle is thus always available without having to vary casting speed and without having to risk casting problems. Feed form the new ladle to the tundish is generally initiated once the minimum tolerable level in the tundish is approached.

The rate of feed to the casting nozzle is determined by the head in the headbox and as a consequence it is important to maintain it at the desired level throughout. The tundish is mounted in such a way that the melt level over the flow route from it to the headbox is kept constant whatever the volume of the tundish. This is achieved in this particular example by using a tilting tundish. This assists in minimising turbulence in the head box and allows the minimal volume possible to be provided in the headbox.

Whilst the tundish can be tilted about any particular axis, the described embodiment is pivotally mounted at the delivery passage into the head box.

As the tundish is initially filled therefore it is tilted down toward the right in Figure 4a. In this way the minimum head requirement 50 is achieved with a low volume of melt. Casting can be initiated once this level has been reached as vortexing is then avoided.

As the mass of melt increases in the tundish as the ladle discharge progresses the tundish is tilted toward the horizontal, Figure 4b, an anticlockwise rotation. The volume of metal is thus increased, but the head 50 is maintained.

The tundish reaches its maximum content value as the ladle finishes discharging, Figure 4c. In this state the

tundish is tilted down to the left such that the majority of the melt is away form the passage to the head box. The head 50 is, however, maintained constant.

As the melt volume in the tundish decreases during further casting the tundish begins to tilt back to the right once more, a clockwise rotation, through the position of Figure 4b to that of Figure 4a. By the time the Figure 4a position is reached another ladle is ready to be discharged into the tundish and the sequence can be repeated as desired. Tilting the tundish in this way is also instrumental in minimising scrap losses in the tundish.

The control of the tundish can be effected by the use of mass sensing and/or level sensing in the tundish or head box.

Whilst the use of a constant head feed from the tundish to a headbox has been described in this example the constant head of the outlet from the tundish could feed direct to the casting nozzle, particularly where a pool is employed in conjunction with the rollers, Figure 1c. In this case a flexible tundish to nozzle connection would generally be employed.

The tundish 22 is illustrated with an enclosed head portion 30 over the delivery outlet 32 to the casting nozzle 26 to allow an inert atmosphere to be employed to protect the steel. Outside this area 30 the steel can be treated with tundish powders to protect the steel from oxidation and to assist in the removal of inclusions. The separation of the areas reduced the risks of tundish powders being carried down and into the casting material.

The tundish can also be used in conjunction with a variety of existing techniques to promote inclusion floating, control mould powder layers and maintain steel quality without effecting the applicability of the present invention.

The overall variation of the parameters, tundish contents; ladle contents; when the ladle to tundish passage is open; and when the tundish to casting passage is open is illustrated in Figure 5 for a number of cycles of the systems operation. Thus initially the tundish is empty (0 tonnes), the ladle is full (40 tonnes) and both ladle to tundish and tundish to casting passages are closed.

The ladle to tundish passage is then opened and during the first passage of time the ladle volume decreases and the tundish volume increases. Once the tundish level reaches the desired level (10 tonnes) the tundish to casting passage is opened and casting begins. Shortly after this the ladle completes its discharge and the tundish is at its maximum value (32 tonnes) for this first cycle.

The tundish contents now decline as casting continues but no new material is feed to the tundish. As the level approaches the minimum tolerable (10 tonnes) a fresh ladle is introduced and the tundish contents are replenished. This sequence is then repeated over and over.

Claims

1. A method of casting comprising feeding molten material to a vessel from a source of molten material, the vessel feeding molten material to a casting location, the molten material being fed to the casting location substantially continuously during casting, the molten material being fed to the vessel from the source for less than 50% of the time during casting.

2. A method according to claim 1 in which the molten material is fed from the source to the vessel for less than 33% of the time.

3. A method of casting, preferably according to claim 1, comprising feeding molten material to a vessel from a source of molten material, the vessel feeding molten material to a casting location through an outlet passage, the volume of molten material in the vessel being variable, the head of molten material over the outlet passage being substantially constant independent of the volume of molten material in the vessel.

4. A method according to any of claims 1 to 3 in which the ratio of maximum to minimum working volume of the vessel is greater than 1.5:1.

5. A method according to claim 4 in which the maximum to minimum working volume of the vessel is greater than 2:1.

6. A method according to any preceding claim in which the flow rate of material from ladle to vessel is at least 1.5 times greater than the casting flow rate.

7. A method according to claim 6 in which the flow rate of material from ladle to vessel is at least 3 times greater than the casting flow rate.

8. A method according to any preceding claim in which the vessel can be adjusted to accommodate varying volumes of material whilst maintaining a constant head.

9. A method according to claim 8 in which the variation is accommodated by altering the position of the vessel, the variation in the positioning occurs through tilting the vessel or pivoting it.

10. A method according to any preceding claim in which the method is used for casting strips of thickness less than 10mm.

11. Casting apparatus comprising a source of molten material, a vessel to which the molten material is

fed, the vessel feeding material to a casting location via an outlet passage, the vessel being adjustable to present a constant head of material independent of the volume of material accommodated within the vessel.

12. Apparatus according to claim 11 in which the vessel is a tundish and heating means are provided for the tundish.

13. Apparatus according to claim 11 or claim 12 in which the vessel is provided with an enclosed head space above the inlet from the vessel to the outlet passage, the enclosed head space being provided with a controlled or inert atmosphere.

14. Apparatus according to any of claims 11 to 13 in which the casting location comprises a casting nozzle and / or the source of molten material is a ladle.

15. Apparatus according to any of claims 11 to 14 in which the vessel is pivotally mounted.

16. Apparatus according to any of claims 11 to 15 in which the apparatus is provided with mass and/or level monitoring means for the vessel and/or for an intervening vessel between the vessel and casting location.

17. Apparatus according to claim 16 in which the intervening vessel comprises a head box.

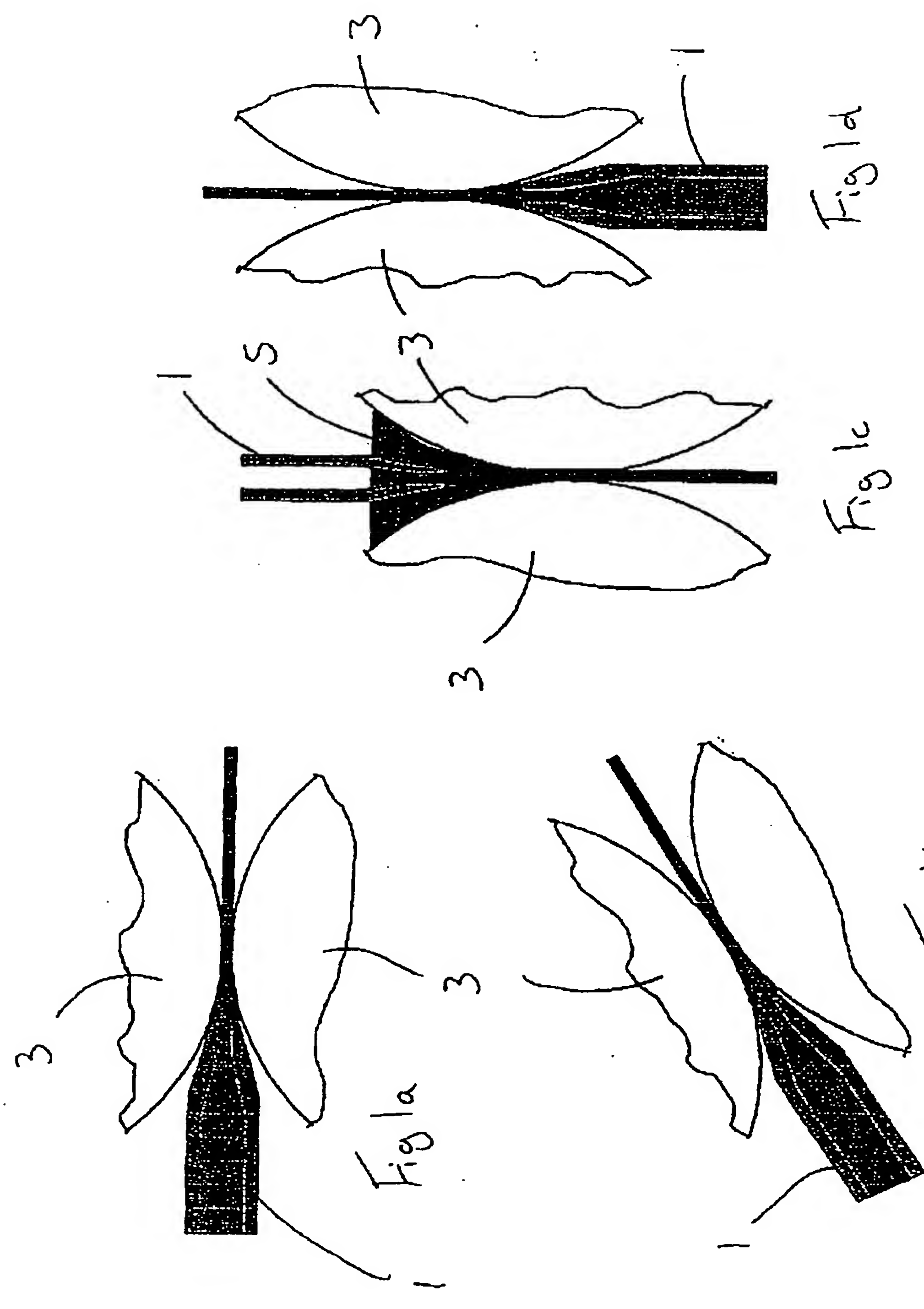


Fig 1a

Fig 1b

Fig 1c

Fig 1d

Fig 2

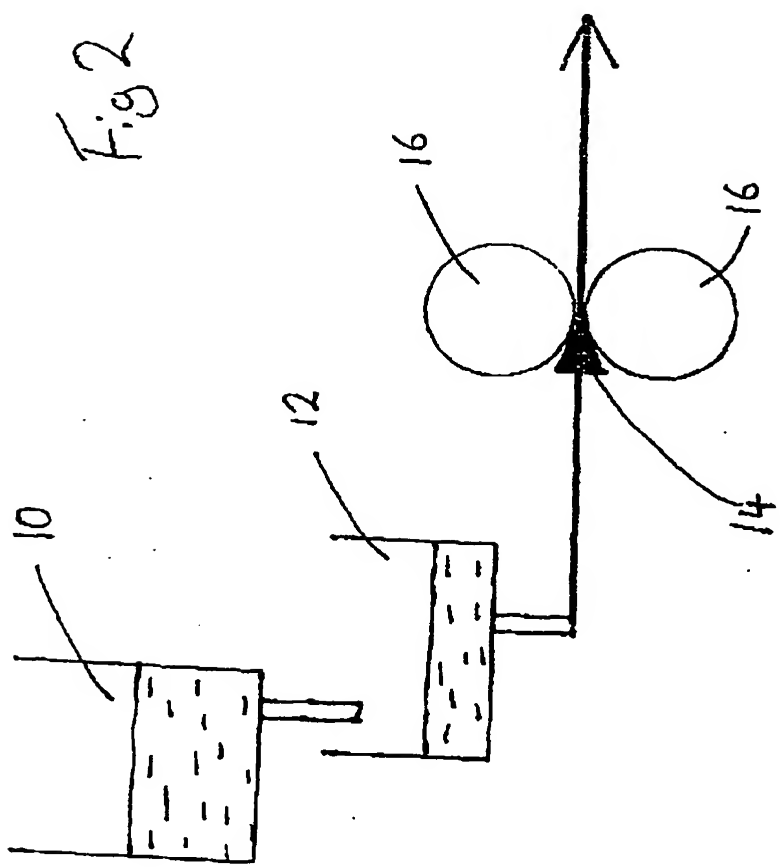
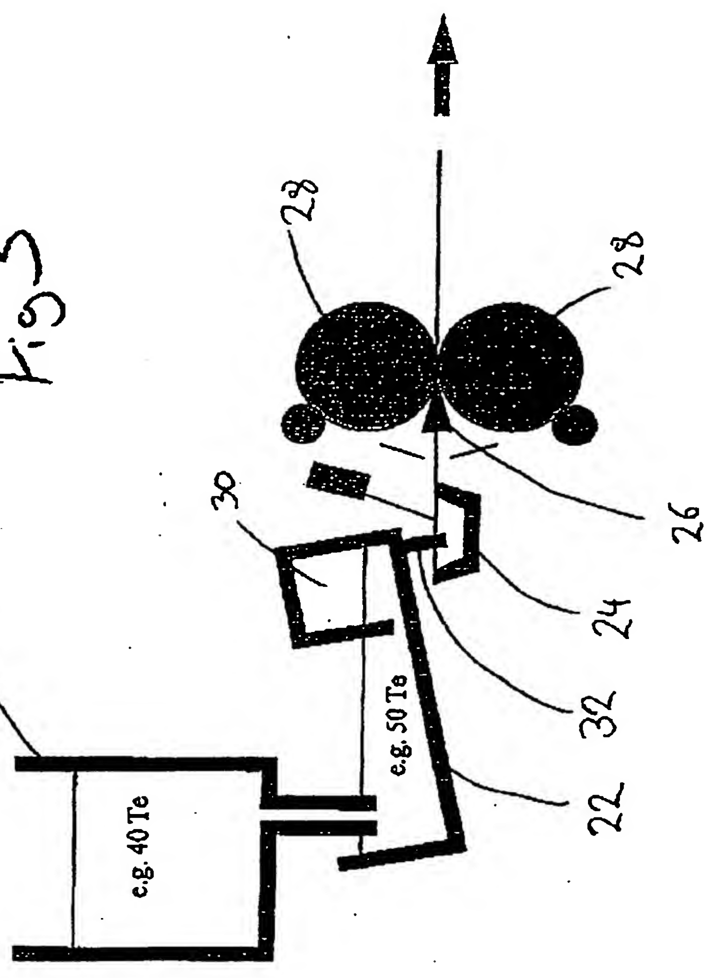


Fig. 3



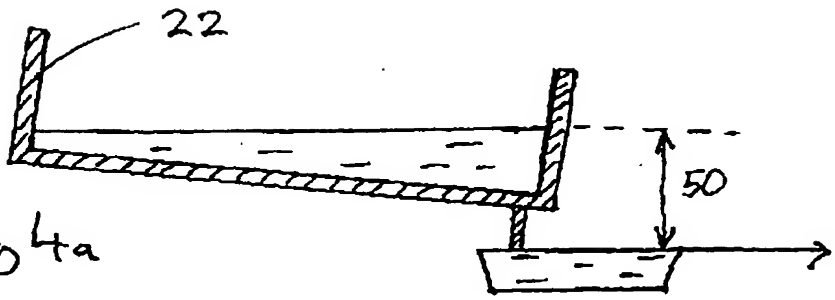


Fig 4a

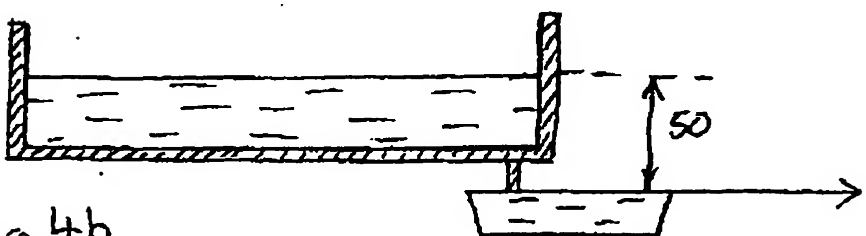


Fig 4b

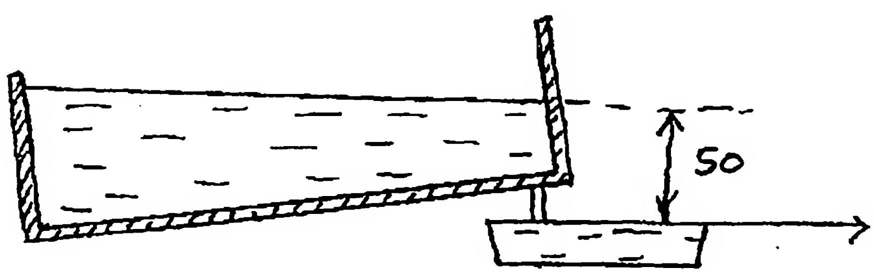
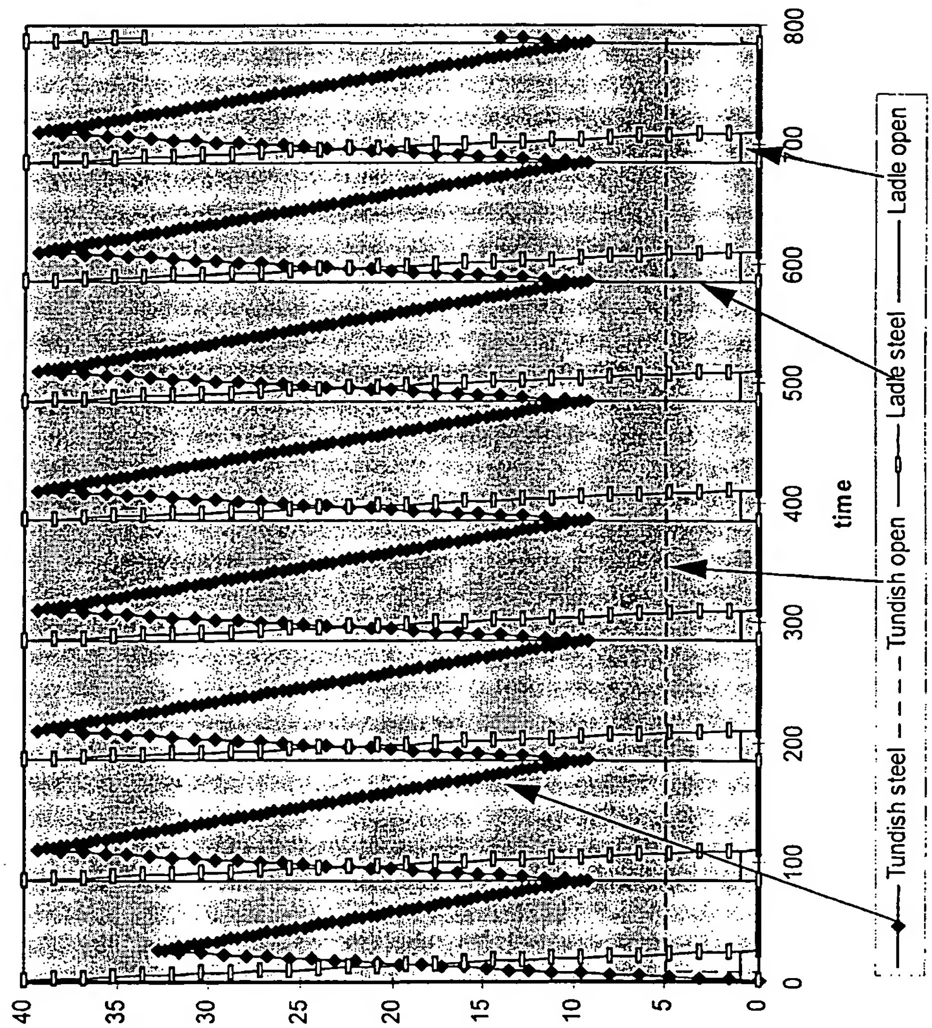


Fig 4c

Fig 5

Fig.3. Flow control



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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 4885

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	LU 45 127 A (DORTMUND-HÖRDER HÜTTENUNION AG, DORTMUND, DE) 28 February 1964 * column 3, line 20 - column 5, line 19 * * figures 1,3 *	1,2,4-7	B22D11/10 B22D11/18
Y		11-16	
A		3,9	
X	DE 21 41 835 A (SOCIÉTÉ NOUVELLE SPIDEM, PARIS, FR) 24 February 1972 * page 4, line 21 - line 26 * * page 7, line 11 - page 8, line 7 * * figure 1 *	11,15,16	
Y		11-16	
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X	PATENT ABSTRACTS OF JAPAN vol. 097, no. 003, 31 March 1997 & JP 08 294752 A (NIPPON STEEL CORP), 12 November 1996	11,14,15	
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Y	* abstract *	11-16	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 October 1998	Peis, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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